solid is scattered in an oblong pear-shaped volume of diameter roughly equal to the electron penetration depth. The penetration depth increases with the energy of the incident electrons Consequently, the diameter of the exposed area is at a minimum when the penetration depth is equal to the film thickness (positing the requirement that the entire thickness of the film be irradiated). Therefore, a means of obtaining improved resolution is by use of a thinner resist film, such as spin-cast organic polymer films or the Langmuir-Blodgett films described previously. However, ultra-thin organic film resists suffer from a number of problems that include film inhomogeneity (particularly pinholes) and the inability to withstand the vigorous plasma etching processes used to transfer the features of the resist to the underlying substrate.

Optical lithographic processes are the most widely employed because they offer the best combination of resolution and throughput. At the present time, the limit of resolution of microcircuitry features that can be produced on a scale practical for commercial production is on the order of one micron. Optical lithography generally involves patterned UV (400 nm or below) irradiation of semiconductor substrates coated with a spin cast organic resist film that is usually 300 nm to one micron thick. Principal limitations to attainment of higher resolution are due to a combination of the wavelength of light employed, the film composition, and photoresist thickness.

In optical lithography, it is known that resolution varies inversely with the wavelength of the irradiation. Therefore, high resolution is achieved by using radiation of the shortest possible wavelength to which the resist is sensitive. A number of light sources suitable for UV irradiation are available, including mercury lamps, xenon lamps, deuterium lamps, surface plasma discharge sources, Nd-YAG lasers, excimer lasers, and optical harmonics generated from the sources. Most of the currently-used high resolution photoresists are sensitive to near-UV (i.e., 320 to 400 nm) light Few, if any known photoresists are useful in the deep-UV (200 to 320 nm) or the vacuum-UV (below 200 nm) regions.

The wavelength of ultraviolet radiation is in the 4 to 400 nm range. That range is loosely divided into near-UV (400 to 300 nm), far-UV (300 to 200 nm), and deep-UV (below 200 nm). Deep-UV radiation is strongly absorbed by air and therefore is usually used in an evacuated apparatus. For that reason, deep-UV is often refered to as "vacuum-UV"

As discussed above for beam techniques, the spin-coated resist films used in optical lithography must be at least several tenths of a micron thick to avoid pinholes and provide adequate resistance to plasma etching. Other limitations to resolution with the use of thick films arise from defocussing of the image in the film, the occurrence of standing waves in the film, Rayleigh scattering from film inhomogeneities and from reduced control of the spatial extent of photoreactions. Spin coating tends to produce films that are thicker at the edges than in the center. Variations in the thickness of the film causes loss of resolution during contact mask exposure (i.e., where a patterned mask is in direct contact with the resist-coated substrate) due to diffraction and defocusing problems. Additionally, spin-coating machines are expensive and the substrates must be coated serially (i.e., one after the other).

Once patterned, conventional optical photoresists generally require chemical development of the image (i.e., removal of the soluble resist material). Solvents employed in development, especially chlorinated hydrocarbons, are known to be particularly environmentally hazardous. Resolution (especially edge acuity) degradation is also induced during development by imperfect dissolution of the resist

Other difficulties encountered with known resist films include imperfect or weak adhesion to the substrate, which can render the piece of work useless if needed resist regions come loose from the substrate. Resist materials often require special care in handling due to their sensitivity to ambient light, moisture and temperature.

Fabrication of metal paths on a semiconductor substrate can be accomplished in a number of ways Generally, a thin metal coating is applied by vapor or sputter deposition over the entire area of the substrate. Most of the metal is removed in a later step following patterning and development steps. No commercial optical lithographic process are believed to currently exist whereby high resolution metal patterns can be selectively deposited.

B. In Relation To Printed Circuitry

In the fabrication of printed circuits, adherent metal patterns are produced on insulative substrates such as organic polymers (e.g., acrylonitrile-butadiene-styrene or polysulfone) and metal oxides (e.g., aluminum oxide). As in the case of semiconductor substrates, metal patterns are generally formed by vapor deposition followed by patterning and removal of most of the metal layer although many other methods are often used.

A variety of procedures are known for the selective deposition of metal initially in only the desired areas of the substrate. In one such procedure employed with a polymeric substrate, a patterned photoresist layer is etched by an acid and the etched resist surface is then activated for metal deposition by exposure to a solution of tin salts and noble metal salts which are applied consecutively or are applied jointly as a mixture. After activation of the etched surface, the substrate is immersed in an electroless plating bath. A typical electroless plating bath contains metal ions, complexing agents, stabilizers and a reducing agent. The reducing agent causes the complexed metal ions to be reduced to metal only in the activated regions. The plated metal surface is itself catalytic for further metal deposition, thus the thickness of the plated layer can be varied by regulating the length of time in which the substrate is immersed in the plating bath. For a report on the technical literature (including patents) pertaining to electroless plating of metal onto polymer substrates, see the monograph entitled "Plating of Plastics -- Recent Developments" by F.A. Domino, Chemical Technology Review No. 138, Noyes Data Corporation, New Jersey (1979).

The general method described above has been employed to produce patterns with 150 micron resolution on epoxy substrates (J K Dorey, et. al., U.S. Pat. No. 4,537,799; granted Aug. 27, 1985). In a related report, metal lines 100 microns in width were fabricated on a polyphenylene sulfide substrate using a procedure in which laser annealing and chemical doping replaced the development and etching steps. These methods involve a considerable number of steps, making them time-consuming and expensive, especially in comparison to the present invention.

It is known that selective activation of an insulative substrate can be accomplished by using stamps or stencils to deposit an "ink" containing either reducible